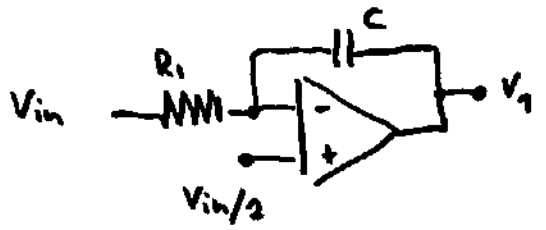
Electronic Complements

23/01/2014

1] The transistor works as an ideal switch. Open circuit or short circuit to ground. (OC or SC)

The left opamp is an integrator. If T is OC:

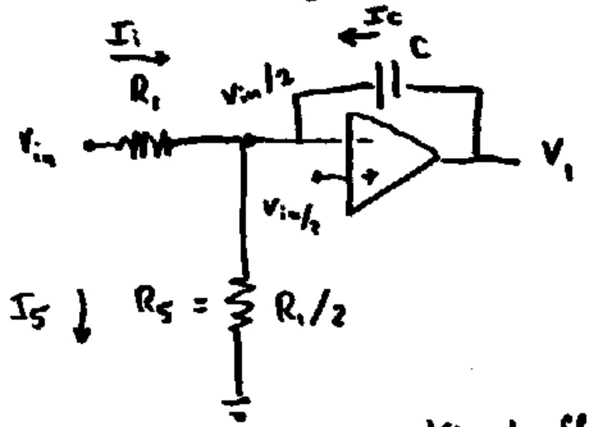


$V_n = V_p = \frac{V_{in}}{2}$. The voltage drop over R_1 is thus $\frac{V_{in}}{2}$, and with ohm's law $I_i = \frac{V_{in}}{2R_1}$. This current flows into C and charges it. $V_1 = V_n - \frac{Q_c}{C} = \frac{V_{in}}{2} - \frac{\int V_{in}\,dt}{2R_1C} + V$

$= V_{00} - \frac{V_{in}\,t}{2R_1C}$, a linearly dropping signal

yet to be determined.

when T is SC:



$V_n = V_p = \frac{V_{in}}{2}$. A current flows through R_1 equal to $I_i = \frac{V_{in}}{2R_1}$

Through R_5 flows a current

$$I_5 = \frac{V_{in}/2}{R_5} = \frac{V_{in}/2}{R_1/2} = \frac{V_{in}}{R_1}$$

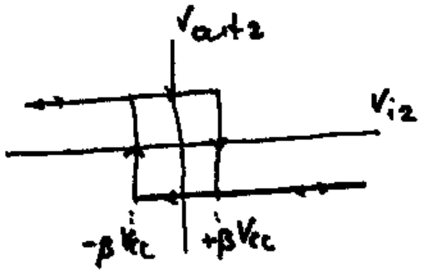
Kirchoff: $I_c = I_5 - I_1 = \frac{V_{in}}{R_1} - \frac{V_{in}}{2R_1} = \frac{V_{in}}{2R_1}$

This current is pulled out of C which is thus ~~~~discharged.

In fact, discharged with the same speed

$$V_i = V_{il} + \frac{V_{in}\, t}{2 R_1 C} \qquad (V_{il} \text{ to be determined})$$

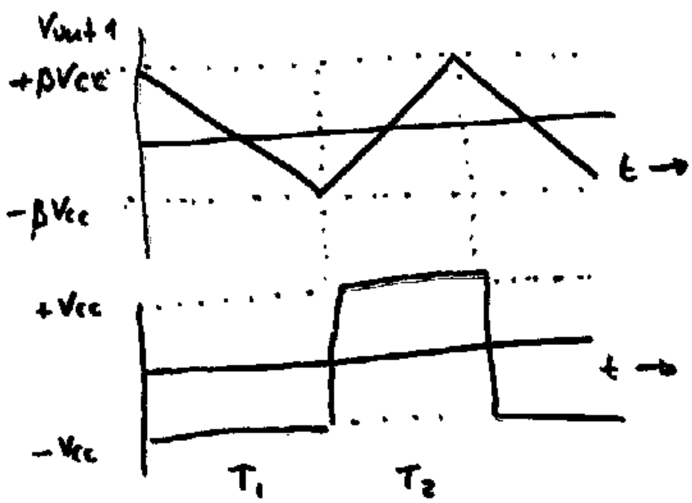
The second opamp implements hysteresis



$$\beta = \frac{R_6}{R_6 + R_7}$$

Combined : The circuit charges and discharges C linearly and periodically.

b)



Note : $V_{iu} = +\beta V_{cc}$
$V_{il} = -\beta V_{cc}$

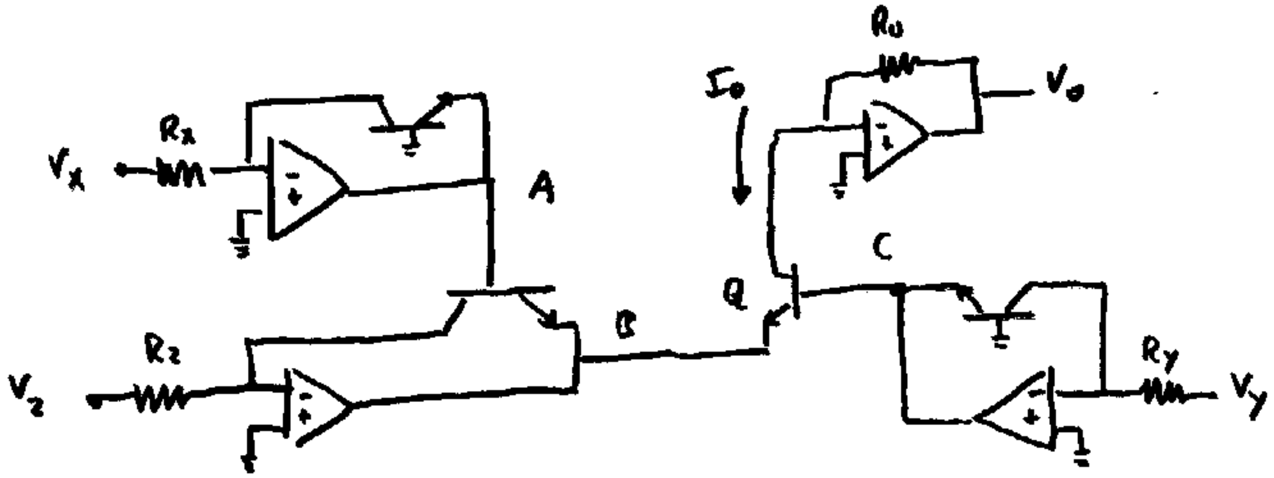
c) A half cycle T_1 is when V_{out1} goes from $+\beta V_{cc}$ to $-\beta V_{cc}$:

$$\frac{V_{in}\, T_1}{2 R_1 C} = 2 \beta V_{cc} \Rightarrow T_1 = \frac{4 \beta V_{cc} R_1 C}{V_{in}}$$

the same for T_2 $(T_2 = T_1)$. thus

$$f = \frac{1}{T_1 + T_2} = \frac{1}{2T_1} = V_{in} \cdot \frac{1}{8 \beta V_{cc} R_1 C}$$

2]



a) All voltages positive $V_x>0, V_y>0, V_z>0$, 1 octant

Ebers Moll (simplificado): $V_{BE} = V_T \ln\left(\frac{I_c}{I_{os}}\right)$

$$V_A = -V_T \ln\left(\frac{V_x}{R_x}\cdot\frac{1}{I_{os}}\right)$$

$$V_B = V_A - V_T \ln\left(\frac{V_z}{R_z}\cdot\frac{1}{I_{os}}\right) = -V_T \ln\left(\frac{1}{I_{os}}\cdot\left[\frac{V_x}{R_x} * \frac{V_z}{R_z}\right]\right)$$

$$V_C = -V_T \ln\left(\frac{V_y}{R_y}\cdot\frac{1}{I_{os}}\right)$$

$$I_o = \frac{V_o}{R_o}, \quad V_{BEQ} = V_T \ln\left(\frac{V_o}{R_o}\cdot\frac{1}{I_{os}}\right)$$

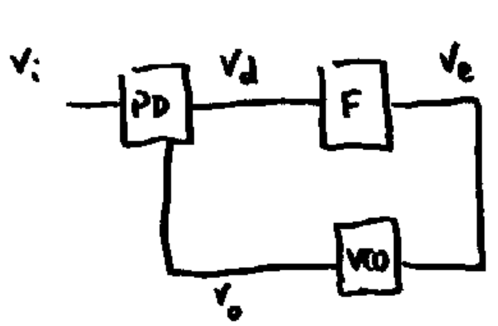
$$V_B = V_C - V_{BEQ} = -V_T \ln\left(\frac{1}{I_{os}}\left[\frac{V_y}{R_y} * \frac{V_o}{R_o}\right]\right)$$

$$\Downarrow$$

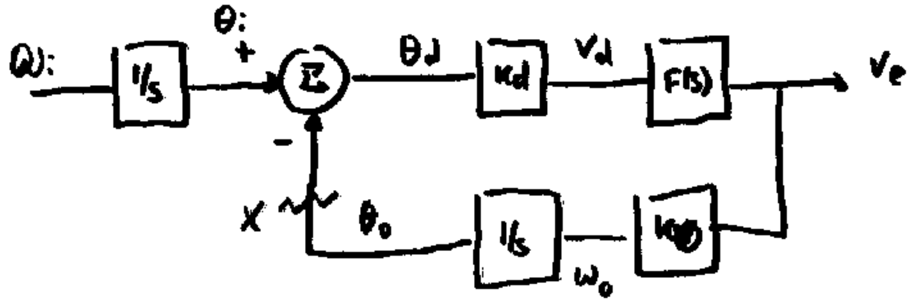
$$-V_T \ln\left(\frac{1}{I_{os}}\left[\frac{V_x}{R_x} * \frac{V_z}{R_z}\right]\right) = -V_T \ln\left(\frac{1}{I_{os}}\left[\frac{V_y}{R_y} * \frac{V_o}{R_o}\right]\right)$$

$$\frac{V_x V_z}{R_x R_z} = \frac{V_y V_o}{R_y R_o} \Rightarrow V_o = \frac{V_x V_z}{V_y}\cdot\frac{R_y R_o}{R_x R_z}$$

3]



a) In Laplace transform of phase, $\theta = \int \omega \, dt$



Open loop : cut at X, then

$$\theta_o = \frac{1}{s} \times K_o \times F(s) \times K_d \times \theta_i$$

$$T(s) \equiv \frac{\theta_o}{\theta_i} = \frac{K_o K_d F(s)}{s}$$

Closed loop

$$\theta_o = \frac{1}{s} K_o F(s) K_d \; (\theta_i - \theta_o)$$

$$H(s) \equiv \frac{\theta_o}{\theta_i} = \frac{T(s)}{1 + T(s)} = \frac{K_o K_d F(s)}{s + K_o K_d F(s)}$$

b) $F(s) = 1$

$$H(s) = \frac{K_v}{s + K_v} = \frac{1}{1 + s/K_v} \qquad K_v = K_o K_d$$

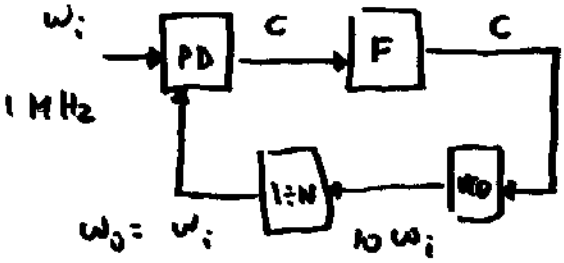
$$\tau = \frac{1}{K_v} = \frac{1}{1V \times 2kHz/V} = \frac{1}{2000}\, s = 0.5 \text{ ms}$$

(Behaves like filter wit $\omega_c = K_v$, or $\tau = 1/K_v$!)

$\tau = 0.5$ ms

$$\omega_o = \omega_2 + (\omega_1 - \omega_2)e^{-t/\tau}$$

c)

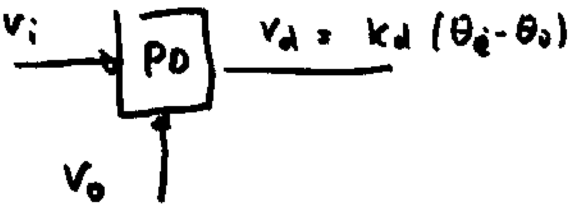


lock? $\Rightarrow$ $\omega_o = \omega_i$

at P.D.

Thus ω at VCO = $10\ \omega_i$, see figure.

4]



$$V_d = K_d(\theta_i - \theta_o)$$

$$\theta_i = \omega_i t = (\omega + at)t$$

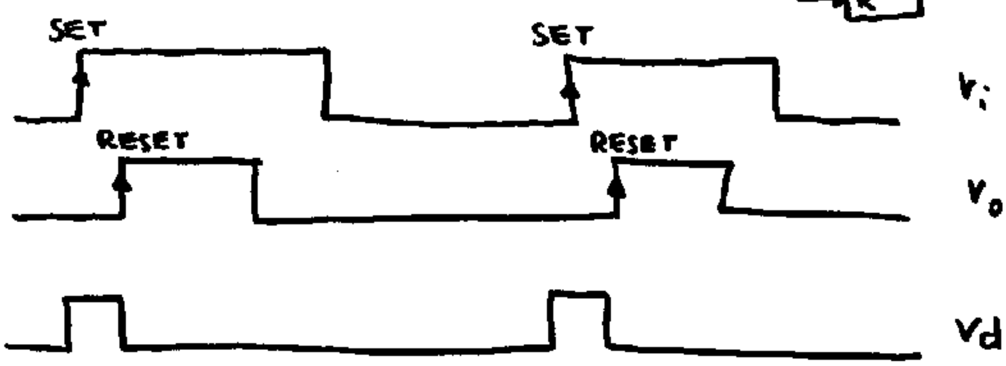
$$\theta_o = \omega_o t = (\omega - at)t$$

$$\theta_i - \theta_o = 2at^2$$

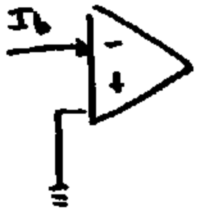
$$V_d = (\theta_i - \theta_o)K_d = 2K_d a t^2$$

(quadratic)

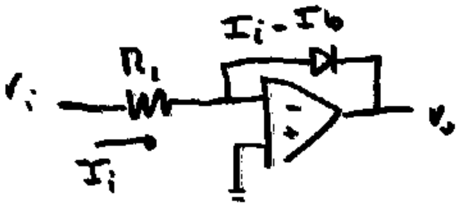
5) See lecture notes



6] See lecture notes



A polarizing current Ib enters into the op-amp, making it non-ideal.



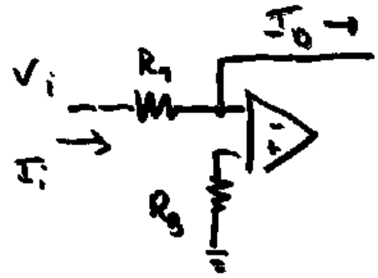
$$V_o = V_T \ln\left(\left[\frac{V_i}{R_1} - I_b\right] / I_{S0}\right)$$

Two ways of avoiding:

1: Inject extra current:

$$I_D = I_1 + I_B - I_B = I_i$$

2: Add resistance to V_p too:



$$V_n = V_p = 0 - I_B R_B$$

$$I_i = \frac{V_i - V_n}{R_1} = \frac{V_i + I_B R_B}{R_1}$$

$$I_D = I_i - I_B = \frac{V_i}{R_1} + \frac{I_B R_B}{R_1} - I_B$$

We see that if $R_B = R_1$, then $I_D = \frac{V_i}{R_1}$ as desired.